

Productivity and profitability of rice (*Oryza sativa*) influenced by customized fertilizers under rice-wheat cropping system

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ABSTRACT

A field experiment was conducted at Agronomy Research Farm, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, on silty loam soil during 2016–17 and 2017–18 to study the productivity and profitability of rice (*Oryza sativa* L.) influenced by customized fertilizers in rice-wheat cropping system. The experiment comprised of 6 nutrient management practices, viz. T₁, control; T₂, recommended dose of fertilizer (RDF); T₃, Soil test-based recommendation (STR); T₄, Indo-Gulf customized fertilizer; T₅, TCL customized fertilizer and T₆, Farmer's practice. The experiment was laid out in a randomized block design with 4 replications. Results revealed that soil test-based recommendation showed significantly higher grain yield (4.88 t/ha), straw yield (7.53 t/ha) of rice, maximum number of effective tillers (438.6/m²), higher length of panicle (25.05 cm), maximum number of grains/panicles (135.10) and test weight (23.81g) over farmer's practice and RDF, while it was at par with TCL customized fertilizer and Indo-Gulf customized fertilizer. The higher buildup of organic soil carbon (0.43%) and available N (174.11 kg/ha), P (18.98 kg/ha), S (14.88 ppm), DTPA-Zn (0.65 ppm) and B (0.55 ppm) in was maintained or slightly increased in soil test-based recommendation and customized fertilizers applied plots. While higher availability of K (259.80 kg/ha) was found in RDF. The higher net returns (32.58 × 10³ ₹/ha) per rupee investment and B:C ratio (0.82) was also recorded in Soil test-based recommendation followed by Indo-Gulf customized fertilizer and TCL customized fertilizer.

Key words: Customized fertilizers, Productivity, Profitability, Rice

Rice is the lifeline for more than half of the world population, and in India. In view of its huge demand in the country; farmers adopt a rice-based cropping system where the irrigation facility is available. As rice is a nutrient-exhausting crop, sustainable productivity of rice-based cropping system greatly depends on appropriate nutrient management in accordance with the inherent soil fertility. The application of an ample dose of fertilizer is the key factor for maintaining sustainable rice yields and nutrient balance of the soil (Sankar *et al.*, 2021). In India, rice and wheat are most important crops for food security accounting for approximately 58% and 77% of the total area and food grain production in the country, respectively (Singh, 2011). The majority of the Indian population lives in villages and the

combined share of these two crops accounted more than 90% of total cereal consumption in rural India (GOI, 2010).

As global grain demand is projected to double by 2050, the challenge to achieve even higher rice production levels still remains. Fertilizer use is one of the major factors for the continuous increase in rice production, more than 20% of fertilizer nitrogen (N) produced worldwide is used in the rice fields of Asia. Irrigated and rainfed lowland rice systems account for 92% of total rice production and nutrients applied as fertilizers account for 20–25% of total production costs in these rice systems (Bijay and Vinod, 2016). Of the total 186.67 MT fertilizer (N + P₂O₅ + K₂O) consumed globally during 2016–17, 14.3% (24.7 MT) was used in rice fields (FAOSTAT, 2018).

Nitrogen (N), phosphorus (P), and potassium (K) are conspired as primary nutrients and are very important for the growth and development of rice (Zhang *et al.*, 2019). Imbalanced nutrient application is one of the most important reasons for multi-nutrient deficiency (Jat *et al.*, 2013). Unless a sufficient amount of other nutrient is applied under such conditions, the crop will continuously drain the

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native soil nutrients. This, when practiced continuously over years, caused, a deficiency in nutrients. Application of nutrients in adequate amount and suitable proportion is the key to crop nutrition. The results of large number of experiments clearly showed that even recommended rates of N, P and K application based on soil test basis, the yield of crops or of the cropping system could not be maintained at higher level continuously (Ananda and Patil, 2005).

The rice-wheat cropping system involving high yielding varieties even with recommended dose of N, P and K use, improve which removes high amount of nutrients from soil and cause deficiency of micro & micro nutrients especially S, Zn, Mn, B and Fe. Use of high analysis fertilizers and inadequate addition of organic manures was resulting in wide spread deficiencies of Zn, S and other micronutrients. The universal deficiency of nitrogen and phosphorus is followed by Zn and nearly 50% of the world soils used for cereal production is Zn deficient (Gibbson, 2006). The growing demand of rice and wheat from increasing population with higher disposable income of farmers requires better nutrient management in crops. To feed the rapidly increasing population of India, the productivity of rice-wheat cropping system must be increased through balanced application of nutrient. Balanced and adequate application of all required nutrients is a key factor for maintain soil fertility and enhancing crop productivity on a sustained basis. There is a need to promote balance fertilization so as to bring the N: P₂O₅:K₂O use ratio close to the ideal 4:2:1.

The promotion of balance fertilization along with adoption of improved management practices will help in sustenance of soil fertility status and enhancement in rice and wheat productivity to the improved farmers' income. Therefore, the most logical way to manage long-term fertility and productivity of soil, site specific nutrient management system is emerging as the most logical concept for managing soil fertility and crop productivity. Soil Test based Recommendation provide information about available nutrient status of soil and thus shall assist the farmers for balanced nutrient application, so as to sustain rice - wheat productivity towards the soil health with increasing farmers' income. The site specific nutrient management approaches based on soil test looked promising are for balanced fertilization avoid indiscriminate use of nutrients by preventing excessive and inadequate nutrient inputs and helps maintain soil health over a long period of time as well as it helps in getting higher yield and uptake of nutrients by crops (Sunil *et al.*, 2015). So maximum grain and economic yields of crops can be achieved by applying all required nutrients including micro and macro (N, P, K, S, Zn, and B) based on soil test values. The customized fertilizers, being alternative source of plant-nutrient resources have gained prime importance in recent decades and they

play a vital role in maintaining long-term soil fertility sustenance. The balance nutrient supply to the rice and wheat crops can be done through customized fertilizers. Customized fertilizers are multi-nutrient carriers designed to contain macro, secondary and micro-nutrient can meet crop nutritional needs which is specific to site, soil and crop. Customize fertilizers for distinct rice crop within rice-wheat cropping systems enhances yields and nutrient utilization. Formulate customized fertilizers based on identified needs. Evaluate the effectiveness of tailored fertilizers on crop productivity. Assess the economic feasibility of customized fertilization practices. Provide practical recommendations for optimizing fertilizer management in rice-wheat cropping systems, contributing to sustainable agricultural practices and improved overall productivity.

MATERIALS AND METHODS

A field experiment was conducted during the *kharif* season of 2017 and 2018 at Agronomy Research Farm of Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh to study the feasibility of site specific nutrient management and customized fertilizers on productivity and profitability of Rice (*Oryza sativa* L.) under rice-wheat cropping system. Geographically, this experimental site falls under semi-arid, sub-tropical climate of Indo-Gangetic alluvial plains (IGP) having alluvial calcareous soil and is located at 26° 47" N latitude and 82° 12" E longitude on an elevation of about 113 meters above mean sea level. The soil of experimental site was silty loam in texture, having pH 7.85, low in organic carbon (0.4%), available nitrogen (161.76 kg/ha), available phosphorus (15.40 kg/ha) and medium in available potassium (248.70 kg/ha), low in available S (9.65 ppm), DTPA extractable Zn (0.50 ppm) and B (0.46 ppm). The experiment was laid out in randomized block design with four replications. There were 6 treatments, viz. T₁, Control (No fertilizer); T₂, Recommended dose of Fertilizers (RDF-150 : 60 : 60 : 25 kg NPK and ZnSO₄/ha); T₃, Soil test based recommendation (STR-120 : 60 : 30 : 30 : 25 : 2 kg N : P : K : S : ZnSO₄ and B/ha); T₄, Indo Gulf-Customized fertilizers-Vardan (N-12%, P₂O₅-26%, K₂O-18%; S, 5% and Zn-0.5%); T₅, TCL-Customized fertilizer-Paras (Rice N-10%, P₂O₅-26%, K₂O-17%, Zn-1% and B-0.3%); T₆, Farmers' Practice (N₁₀₀ P₄₀ K₀). The half dose of N and full dose of P₂O₅ and K₂O, S, Zn and B were applied as basal, applied at the time of last puddling, through urea, diammonium phosphate, muriate of potash, elemental sulphur, zinc sulphate and borex respectively as per treatment. Remaining N was top dressed in 2 equal splits at the time of maximum tillering and panicle initiation stages, respectively. In treatment T₃ (STR), on the basis of soil test values, the sulphur, zinc and boron were applied at last pud-

dling through elemental sulphur, zinc sulphate and borax, respectively. The customized fertilizers were applied as per treatments at last puddling. The rice variety 'NDR-359' was transplanted in the first week of July at 20 cm × 15 cm crop geometry. The soil samples collected from the experimental field were processed and analyzed for experimental studies. The samples were air dried, and prepared for the analysis of soil parameters like pH, EC (1 : 2.5 soil : water) by using glass electrode pH meter (Jackson, 1973), Organic Carbon by using Walkley and Black's rapid titration method (Walkley and Black, 1934), available nitrogen was analyzed by alkaline permanganate method (Subbiah and Asija, 1956), available phosphorus by Olsen's method (Olsen *et al.*, 1954), available potassium by flame emission spectrophotometer (Jackson, 1973), available sulphur by using 0.15% CaCl₂ method (Chesnin and Yien, 1950), Zinc and Iron estimated by Atomic Absorption Spectrophotometer method, respectively. The data were analyzed statistically by analysis of variance method for randomized block design (Gomez and Gomez, 1984). Economic efficiency of various treatments taken in this study was worked out on the basis of input-output relationship with respect to net return (× 10³ /ha) and benefit-cost ratio (B: C). The minimum support price of rice crop during the field experimentation was taken into account for this purpose.

RESULTS AND DISCUSSION

Pooled mean of two years data revealed that the mean grain yield of rice was significantly higher with combined application of macro and micro nutrient. Application of fertilizer N, P, K, S, Zn and B at soil-test based recommended rates (T₃, STR-where most of the required nutrients i.e. N, P, K, S, Zn and B supplied in balanced amount) produced an average yield of rice (4.88 t/ha), which was significantly higher than unfertilized control (1.83 t/ha), RDF (4.24 t/ha), and farmers' practices (2.83 t/ha) and statistically at par with Indo Gulf- Customized Fertilizers-

Vardan (4.83 t/ha) and TCL- Customized Fertilizes-Paras (4.75 t/ha). The yield of rice with 100% RDF (4.24 t/ha) was significantly higher than control (1.83 t/ha), farmers' practice (2.83 t/ha) and statistically lower than soil-test based recommended dose (4.88 t/ha), Indo Gulf-Customized Fertilizers-Vardan (4.83 t/ha) and TCL- Customized Fertilizes-Paras (4.75 t/ha). Soil-test based (N, P, K, S, Z & B) application, gave similar results as application of Indo-Gulf and TCL-customized fertilizers. It is apparent from the data (Table 1) that the grain yield of rice was found significantly higher under most of the treatments over T₁-Control (1.83 t/ha) and Farmers' practices (2.83 t/ha). Similar trend was also found in case of straw yield of rice. The application of nutrients according to Soil Test base recommendation (T₃), the grain yield of rice was increased 62.47 %, 13.07 %, 0.88%, 2.66% and 41.88% over control, RDF, Indo-Gulf-customized fertilizer, TCL-customized fertilizer and farmers' practice respectively. Similarly, Under Indo-Gulf-CF and TCL-CF the grain yield of rice was increased 62.08%, 12.21% and 41.31% and 61.45%, 10.70% and 40.29% over Control, RDF and farmers' practices respectively. The yield difference under both the customized fertilizers and soil test based recommendation was not up to the level of significant. Application of RDF, the grain yield of rice was increased 56.83% and 33.16% over control and farmers' practices respectively. Similar trend was also observed in straw yield, (Kumar, 2009) also reported that higher crop productivity can only be achieved and sustained through supply of all plant nutrients in proportion matching with a crop's needs is maintained through site specific nutrient management based on soil testing values lead to increase yields and profit by providing the correct amounts on needed nutrients.

Yield attributes

Yield attributes viz., number of effective tiller/m², number of grains/panicles and length of panicles (cm) increased

Table 1. No. of effective tiller/m², length of panicles (cm), grains/panicles, test weight, harvest index, rice yield and straw yield affected by various treatments (Mean of 2 years)

Treatment	Effective tillers/m ²	Length of panicles (cm)	Grains/panicles	Test weight (g)	Harvest index (%)	Rice yield (t/ha)	Straw yield (t/ha)
Control (No fertilizer)	183.6	18.7	61.5	22.41	38.02	1.83	2.97
Recommended dose of fertilizers (RDF)	387.6	22.7	127.4	23.12	38.73	4.24	6.90
Soil test-based recommendation –STR (N, P, K, S, Zn, B)	438.6	25.05	135.1	23.81	39.29	4.88	7.53
Indo Gulf-Customized fertilizers-Vardan	430.4	24.4	131.2	23.62	39.53	4.83	7.39
TCL-Customized fertilizer Paras	423.3	24.05	127.2	23.21	39.55	4.75	7.25
Farmers' Practice	265.2	20.2	96.35	22.81	38.86	2.83	4.45
SEm±	13.01	0.65	3.14	0.59	-	0.83	2.29
CD (P=0.05)	39.24	1.98	9.50	1.82	NS	2.49	6.92

RDF, Recommended dose of fertilizer; TCL, Tata Chemical Limited; STR, Soil test based recommendation

significantly with all the treatments than unfertilized control and farmers' practice. Application of N, P, K, S, Zn and B at soil-test based recommended rates significantly increased the number of effective tiller/m² (438.6), number of grains/panicles (135.1) and length of panicles (25.05 cm) as compared to control, RDF and farmers' practice and these were at par with Indo-gulf customized fertilizer and TCL-customized fertilizers respectively. The Soil Test based recommendation (STR)-where most of the required nutrients i.e. N, P, K, S, Zn and B supplied in balanced amount as required by crop, which stimulated the growth and yield of crops and also improved the availability of nutrient in soil as per crop needs. The superiority of the treatment is explained on the basis of balanced nutrient supply which enhances cell division, photosynthesis and reproductive phases resulted more effective tiller/m² and length of panicles. This might be because of improved the nutrient availability, thereby improving the efficiency and utilization of native as well as applied nutrients (Ahmad and Irshad, 2011) reported similar result.

Harvest index is the indicator of grain yield per cent of the biological yield in the respective treatment. It increased due to application of balanced nutrient in the order of increasing the grain yield of rice. Treatments soil-test based, Indo-gulf customized fertilizer and TCL-customized fertilizers, showed the higher values of harvest index of 39.29%, 39.53% and 39.55% respectively and lower values of harvest index was found with control (38.02 %), RDF (38.73%) and farmers practices (38.86%). The increases in harvest index were due to balanced nutrient management. Thereby improving the efficiency in utilization of nutrient as well as applied nutrients which ultimately improved the yield attributing characters of crop. Similar finding were also reported by Singh *et al.* (2008), Rahman *et al.* (2011).

The effect of balanced nutrient management practices on test weight reveals that the higher values of test weight was found under the soil test based recommendation STR

(23.81g) followed by Indo Gulf-Customized fertilizers-wardan (23.62g) and TCL- Customized fertilizers-Paras (23.21g) while minimum in control (22.41g), and farmers' practices (22.81g). The test weight slightly increased with soil test based recommendation and both customized fertilizers might be due to relatively more nutrient supply in balanced amount and as per crop need which enhance the plant growth behavior and increased test weight. Similar finding were also reported by Singh *et al.* (2006).

Changes of nutrient status in soil

The buildup of organic carbon, availability of nutrients (OC, N, P, K, S, Zn and B) was influenced under most of the treatments due to different nutrients management practices. The organic carbon content in soil was recorded in the range of 0.36 to 0.43% after harvesting of rice. The organic carbon content showed slightly declining trend from its initial value under control and farmers' practice while marginal build-up in organic carbon content were observed with balanced use of fertilizers. The organic carbon did not show much increase however, slightly buildup of was observed by applying all required nutrients including micro and macro (N, P, K, S, Zn and B) based on soil test value basis and customized fertilizers. This increase in organic carbon may be due to supply of S, Zn and B along with N, P and K in balanced amount to deficient soil, resulting in higher root and shoot growth and thus increased in production of biomass might have raised the organic carbon content in soil. Maximum build-up of organic carbon 0.43% and 0.45% was recorded under the treatment soil test based recommendation (STR) while minimum (0.36%) and (0.35%) under control respectively after harvesting of rice crop. Similar results were found by Singh *et al.* (2015) and Yadav *et al.* (2021).

Available N, P and K in Soil

The availability of N, P and K in soil after harvesting of rice was influenced under most of the treatments due to

Table 2. Effect of various treatments on nutrients availability after harvest of rice (mean of 2 years)

Treatment	OC (%)	N (kg/ha)	P (Kg/ha)	K (kg/ha)	S (ppm)	Zn (ppm)	B (ppm)
Control (No fertilizer)	0.36	145.53	13.43	235.70	8.48	0.53	0.43
Recommended dose of fertilizers (RDF)	0.40	156.88	17.75	259.80	12.14	0.63	0.45
Soil test base recommendation-STR (N, P, K, S, Zn, B)	0.43	174.11	18.08	255.35	14.88	0.65	0.55
Indo Gulf Customized fertilizers-Vardan	0.43	170.05	18.78	256.60	13.53	0.65	0.51
TCL-Customized fertilizer-Paras	0.42	173.48	18.98	254.55	11.67	0.64	0.54
Farmers' Practice	0.39	153.72	15.28	241.13	9.15	0.54	0.43
SEm±	0.01	3.01	0.45	3.47	0.48	0.01	0.006
CD (P=0.05)	0.03	9.08	1.36	10.45	1.49	0.04	0.02

RDF, Recommended dose of fertilizer; TCL, Tata Chemical Limited; STR, Soil test-based recommendation

Table 3. Economics of various treatments in rice (mean of 2 years)

Treatment	Cost of cultivation ($\times 10^3$ ₹/ha)	Gross returns ($\times 10^3$ ₹/ha)	Net returns ($\times 10^3$ ₹/ha)	Benefit: cost ratio
Control (No fertilizer)	33.76	27.92	58.35	0.17
Recommended dose of fertilizers (RDF)	44.03	65.79	21.76	0.49
Soil test-based recommendation-STR (N, P, K, S, Zn, B)	41.00	73.58	32.58	0.82
Indo Gulf- Customized Fertilizers-Vardan	42.81	73.03	30.22	0.71
TCL-Customized fertilizer-Paras	43.06	71.95	28.89	0.67
Farmers' Practice	38.54	43.12	4.58	0.12

RDF, Recommended Dose of Fertilizer; TCL, Tata Chemical Limited; STR, Soil test based recommendation

different nutrient supply combinations. The availability of N, P and K were recorded in the range of 145.53 to 174.11 kg/ha, 13.43 to 18.98 and 235.70 to 259 kg/ha respectively. The N, P and K content in soil showed declining trend from their initial values (N 161.76, 15.40 and 248.70 kg/ha) under control and Farmers' practice. While showed increasing trend with the soil test based recommendation (STR), RDF, Indo-Gulf-customized fertilizer and TCL-customized fertilizer, because balanced fertilizers are efficient for building-up of N, P and K. Maximum depletion of N, P and K were observed in Farmers' practice and control (No fertilizers), where imbalanced and inadequate amount of nutrients were supplied could not increase the N, P and K availability considerably as compare to their initial values. The availability of N, P and K in soil after harvesting of rice increased significantly under the treatments soil test based recommendation (STR), RDF, Indo-Gulf-customized fertilizer and TCL- customized fertilizer as compared to their initial values, Control and farmers' practice respectively. (Kumar and Yadav, 2005) also reported that the decline in productivity of rice and wheat with continuous cropping was related to deficiency of N, P, K, S and Zn and imbalanced nutrition and hence maintenance of soil fertility and sustainability in yield could be achieved only the balanced dose of fertilizers (Singh *et al.* 2015) also reported that at the end of the experiment, the soil available N, P, K, S, Zn, and B content were either maintained or improved over their initial values in site specific nutrient management practice. This result confirms the findings of Jat *et al.* 2019.

Status of S, Zn and B

The availability of S, Zn and B were significantly influenced under most of the treatments as compare to farmers' practice and control. The availability of S, Zn and B were recorded in the range of 8.48 to 14.88, 0.53 to 0.65 and 0.43 to 0.55 ppm respectively. Slight depletion in available S, Zn and B status of soil were observed under control and farmers' practice as compared to their initial values. However, the status of S, Zn and B maintained or slightly en-

hanced under T₃ (STR), T₄ (Indo-Gulf-CF) and T₅ (TCL-CF). Maximum availability of S, Zn and B were found with the treatments T₃ (STR), T₄ (Indo- Gulf-CF) and T₅ (TCL-CF) which were significantly higher over control, farmers' practice and their initial values of soil. Similar result was found in the finding of Ahmed *et al.*, (2014).

Economics of treatments

The maximum net returns of rice (32.58×10^3 ₹/ha) and B: C (0.82) was noted by applying all required nutrients including micro and macro (T₃, Soil test- based recommendation –STR (N, P, K, S, Zn and B) which was higher than net return and B: C ratio obtained with RDF (21.76×10^3 ₹/ha) and B: C (0.49) and farmers practices (4.58×10^3 ₹/ha) and B: C (0.12) and very close with Indo-Gulf customized fertilizers (30.22×10^3 ₹/ha) and B: C (0.87) and TCL-customized fertilizers (28.89×10^3 ₹/ha) and B: C (0.67) respectively. while, negative net returns and B: C were found in control where no source of fertilizers were used in rice crop. Similar findings were found in results of Dwivedi *et al.*, (2014) and Kumar *et al.*, (2009).

Thus it may be concluded that, for achieving and sustaining higher economic yields of rice, application of required secondary nutrient (S) and micro nutrients (Zn and B) which are below the critical level in soil is necessary used with soil test based dose of N, P, K.

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